EXP-NOTE 148

UNDERSTANDING THE 200 MEV LINE

S.D. Holmes
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In an attempt to understand the optics of the 200 MeV transfer line between the Linac and Booster in its present configuration a series of beam profiles were taken while simultaneously documenting the settings and readbacks of all quadrupoles downstream of the chopper. A least squares fitting program has been used to fit the observed profile widths using as free parameters the lattice functions at the downstream end of the chopper, the beam transverse emittances, and the momentum spread. The fitting program assumes the strengths of the quadrupoles is known as a function of the excitation.

Results

Specifically, what I have done is as follows:

I. Fit the horizontal and vertical profile widths through multiwire 8 using as free parameters,

$$\beta_H,\ \alpha_H$$
$$\beta_V,\ \alpha_V$$
$$\epsilon_H,\ \epsilon_V$$
$$\sigma_p/p.$$

All lattice functions are referred to the downstream end of the chopper. I explicitly assume that the horizontal dispersion is given by the chopper deflection (i.e. the dispersion is zero upstream of the chopper), and that the vertical dispersion is zero. The proportionality constant between current and strength in the quadrupoles was varied by hand, and was found to give a best fit at a value 3% below that given on the console page B66. A very good fit is obtained as shown below.

Multiwire	Sigma(Observed,mm)	Sigma(Fit,mm)
Horizontal		
MW1	4.0	3.9
MW2	1.3	1.4
MW3	6.2	6.4
MW4	1.9	2.1
MW5	5.8	5.6
MW6	4.5	4.5
MW8	7.2	7.2
Vertical		
MW1	1.6	1.5
MW2	5.5	5.4
MW3	4.1	4.3
MW4	5.1	5.2
MW5	5.9	5.9
MW6	2.3	2.3
MW7	7.7	7.6
MW8	1.6	1.6

The best fit parameters are,

$$\beta_H=1.26 \text{ m}$$
$$\alpha_H=0.15$$
$$\beta_V=21.2 \text{ m}$$
$$\alpha_V=6.19$$
$$\epsilon_H=9.6\pi \text{ mm-mr}$$
$$\epsilon_V=9.1\pi \text{ mm-mr}$$
$$\sigma_p/p=2.6\text{x}10^{-3}.$$

The best value for the strength of a 200 MeV quadrupole turned out to be 0.5179 kGauss/Amp assuming the energy of the beam is 204 MeV. Both the values of the lattice functions and the strength of the quadrupoles are in reasonable agreement with an analysis of the forward (i.e. toward the spectrometer) line performed earlier this year by Chuck Schmidt.

II. Fit the horizontal profile widths of multiwires 9-12 using the parameters obtained above except that the momentum spread and the strength of Q21 are allowed to vary. Multiwire 9 is the wire immediately downstream of the Debuncher. The vertical profile shows that the beam has obviously been scraped somewhere between wires 8 and 9 (see Figure 1). Thus, all the vertical measurements after the Debuncher are suspect. The horizontal wires are fit to a new momentum spread since the momentum spread is changed by the Debuncher. Q21 is allowed to vary because it is of a different construction than the other quadrupoles in the line. The results of the fit are,

Multiwire	Sigma(Observed,mm)	Sigma(Fit,mm)
Horizontal		
MW9	1.8	2.0
MW10	2.3	2.4
MW11	1.8	1.3
MW12	5.1	5.3

The best fit value for the momentum spread is consistent with zero. This is because there are no locations in this section of the line where the dispersion is large enough for the momentum spread to make any appreciable contribution to the beam size. The best value for the strength of Q21 is 0.1636 kGauss/Amp, again assuming 204 MeV.

I regard the fits as really quite good. We can now proceed to display the optics of the 200 MeV line for the fit parameters given above. This is done in Figure 2 where the solid/dashed heavy lines are the horizontal/vertical beta functions and the solid/dashed thin lines are the horizontal/vertical dispersion. This is my best guess as to what the 200 MeV line optics is at the present time. Also shown on the figure are the multiwire locations.

The figure shows several interesting features in this line. First, it shows that the vertical beam size is very big at multiwire 9--the downstream end of the Debuncher. The vertical beam size here would be about 51 mm (95% full width) if the emittance were preserved from the beginning of the beam line. ***Unfortunately the aperture of the Debuncher is only 4 cm!*** So it is obvious why the vertical profiles downstream of the Debuncher are messed up.

The second interesting feature is that there is a large vertical dispersion induced by the magnets which bring the beam down the chute (MV1 and MV2). This vertical dispersion is not supressed before the line enters the Booster. The horizontal dispersion match into the Booster is also not very good.

We can also see from the figure that the beam is extremely small at Q21, the location of the large aperture quadrupole. The placement of this quadrupole must represent some old optical condition. The largest vertical beam size is actually obtained at Q24.

Suggestions

I have calculated a new set of quadrupole currents which might serve us better. They are given in Table I. Note that several quadrupoles need to reverse polarity. The lattice predicted for the new optics is shown in Figure 3. The following improvements are provided by the new optics:

1. The vertical dispersion is killed downstream of the chute.

2. The beam is kept realtively small (22 mm) in both dimensions through the Debuncher.

3. The maximum beta anywhere in the line is reduced from 85 meters to 50 meters.

4. The horizontal dispersion is better matched into the Booster.

I would suggest implementing these settings sometime during one of our Booster studies periods. The predicted profile widths for these settings are given in Table II.

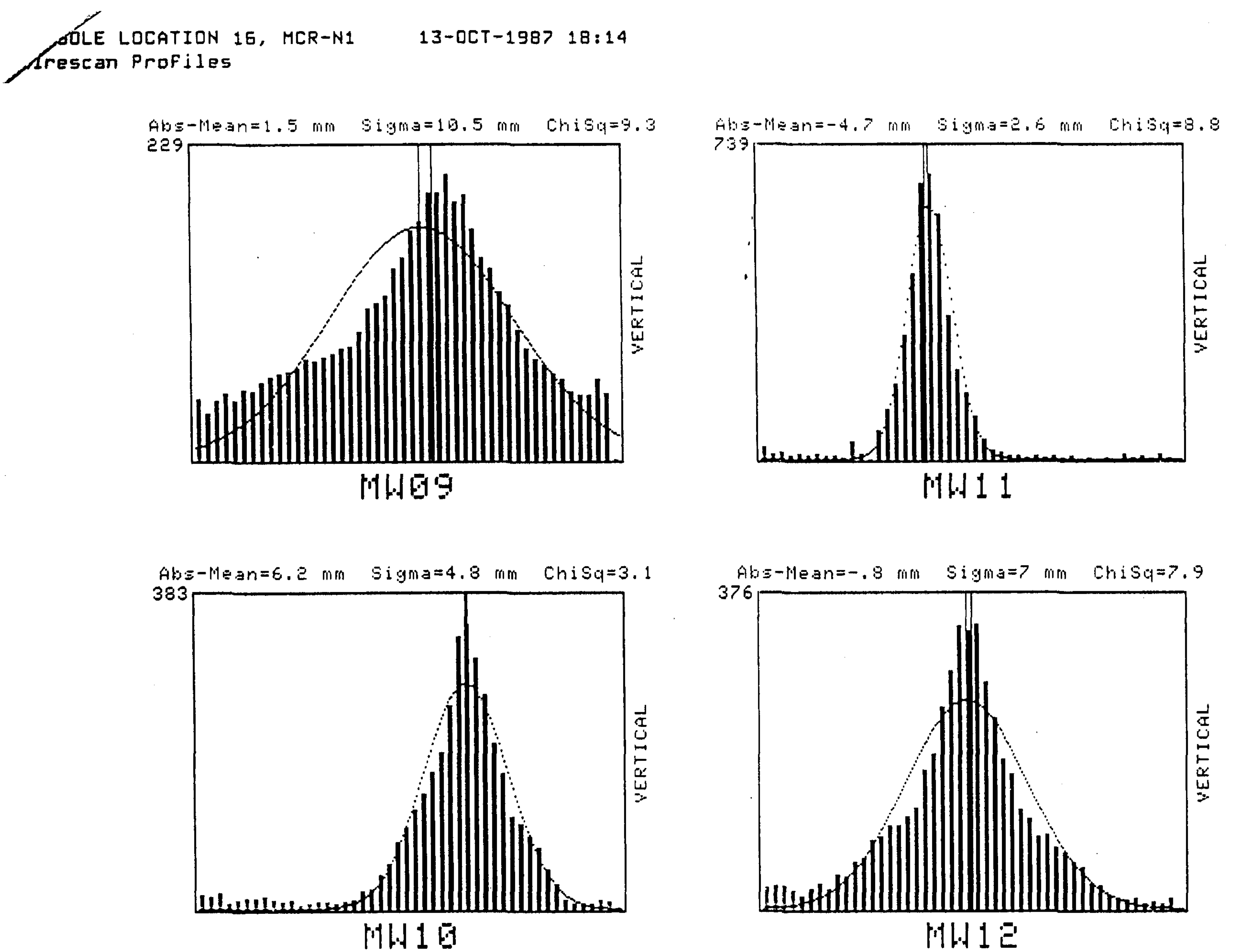

Figure 1. Vertical Profiles Downstream of the Debuncher.

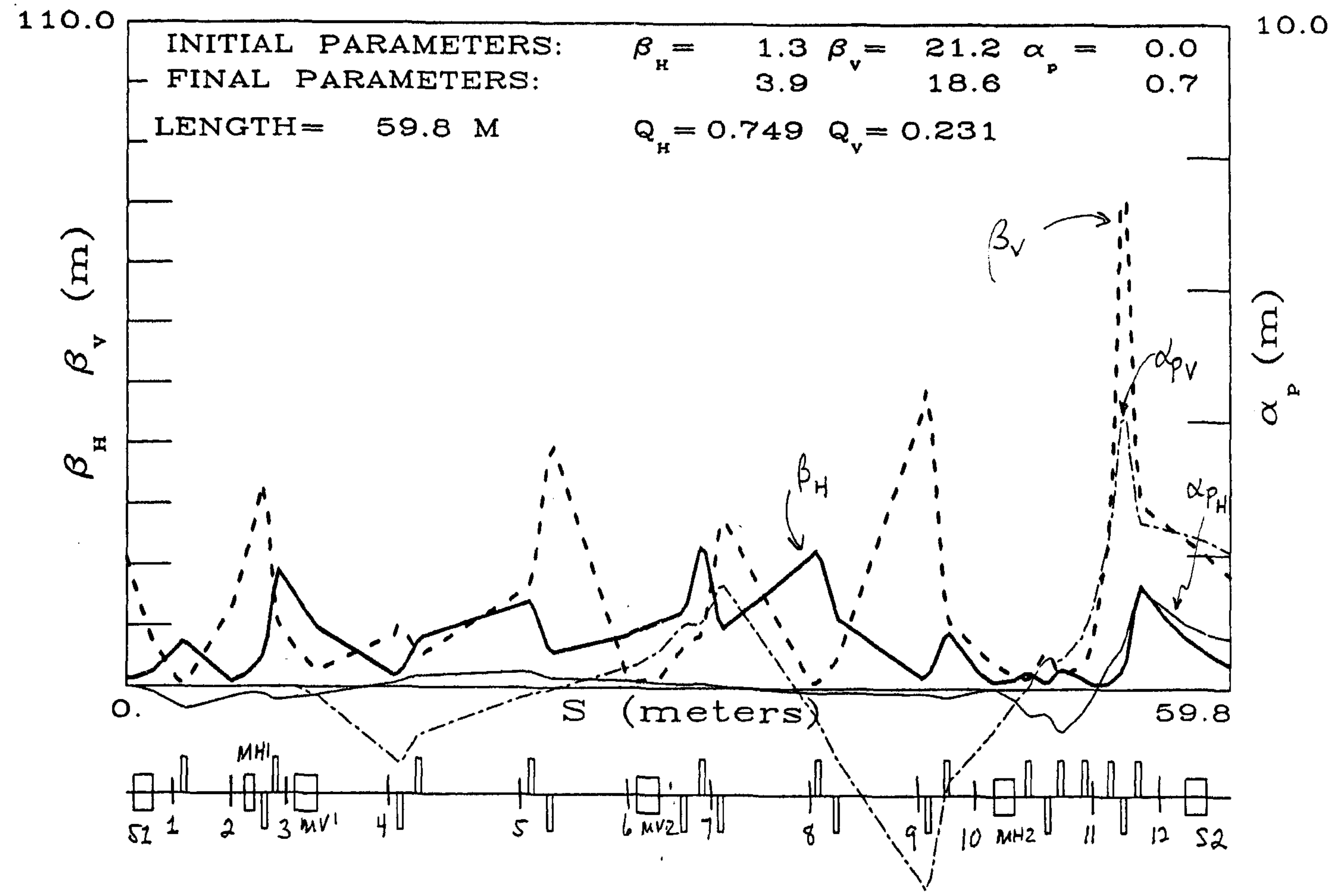

Figure 2. Best Fit to the Current 200 MeV Line Optics

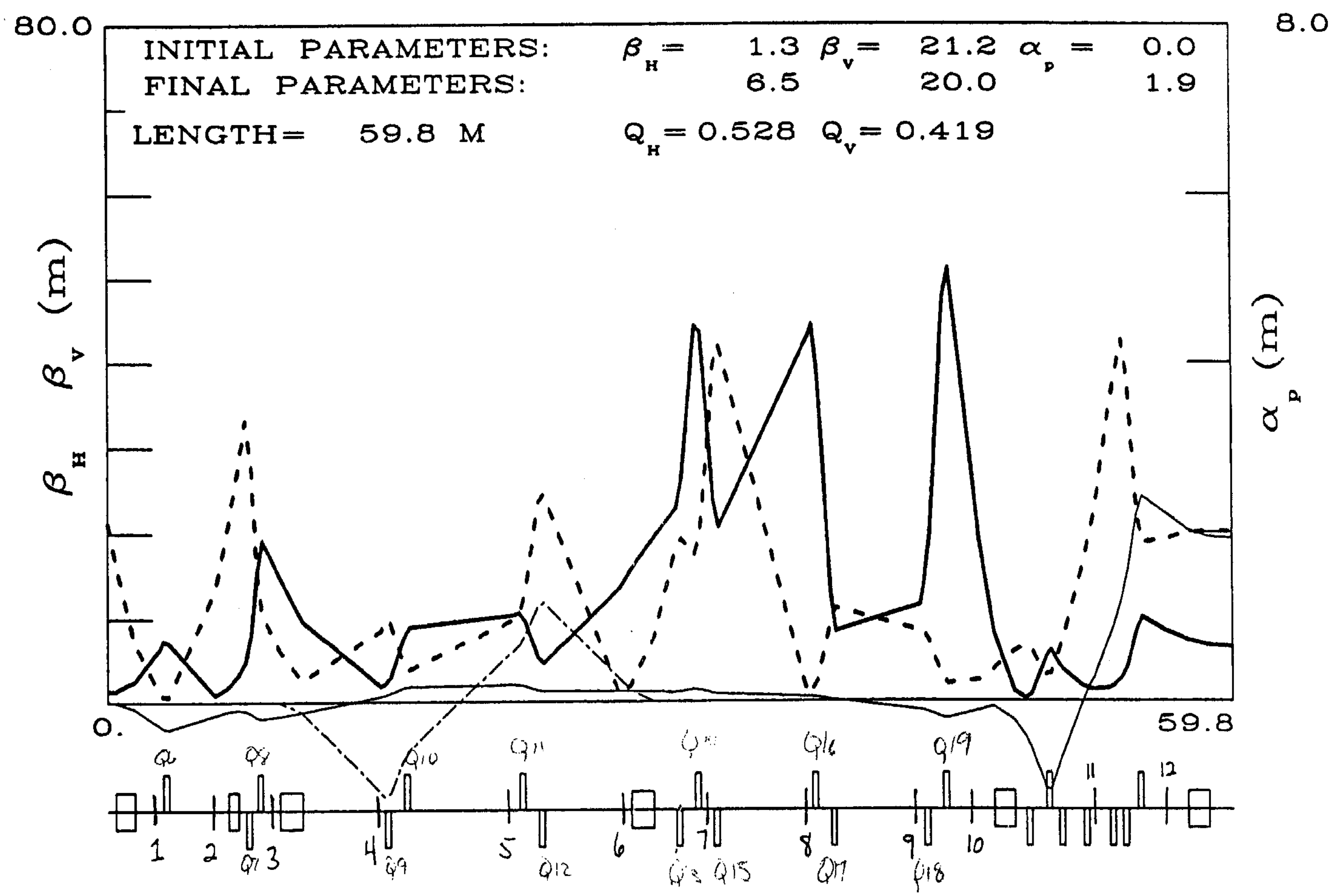

Figure 3. 200 MeV Line Optics for Quadrupole Settings in Table I.

Table I. New 200 MeV Quadrupole Currents (A/D)

Quadrupole	Old Current	New Current
Q6	29.2	29.2
Q7	40.7	40.7
Q8	39.9	39.9
Q9	25.3	29.3
Q10	20.6	23.4
Q11	18.8	17.5
Q12	23.6	26.4
Q13	14.7	15.7
Q14	29.3	28.7
Q15	28.3	26.0
Q16	14.9	26.2
Q17	6.1	30.0
Q18	28.8	21.8
Q19	36.9	30.7
Q20	44.5	20.4**
Q21	147.3	139.7**
Q22	43.5	0.
Q23	41.0	1.7
Q24	28.3	4.7**
Q25	54.0	25.0
Q26	39.9	29.1

** POLARITY REVERSED

Table II. Expected Profile Widths for New 200 MeV Optics

Multiwire	Horizontal Sigma(mm)	Vertical Sigma(mm)
MW1	3.9	1.5
MW2	1.5	5.4
MW3	6.3	4.3
MW4	2.1	5.1
MW5	4.9	4.9
MW6	5.6	1.4
MW7	8.2	8.5
MW8	10.0	1.2
MW9	5.2	4.3
MW10	6.7	2.3
MW11	1.8	7.0
MW12	4.9	6.5